External Peer Review of DOE Benefits Forecasts

Electricity Delivery and Energy Reliability

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OE Mission Statement

Lead national efforts to modernize the electric grid, enhance security and reliability of the energy infrastructure, and facilitate recovery from disruptions to energy supply.

- **Research & Development (R&D)**
- **Permitting, Siting, & Analysis (PSA)**
- **Infrastructure Security & Energy Restoration (ISER)**

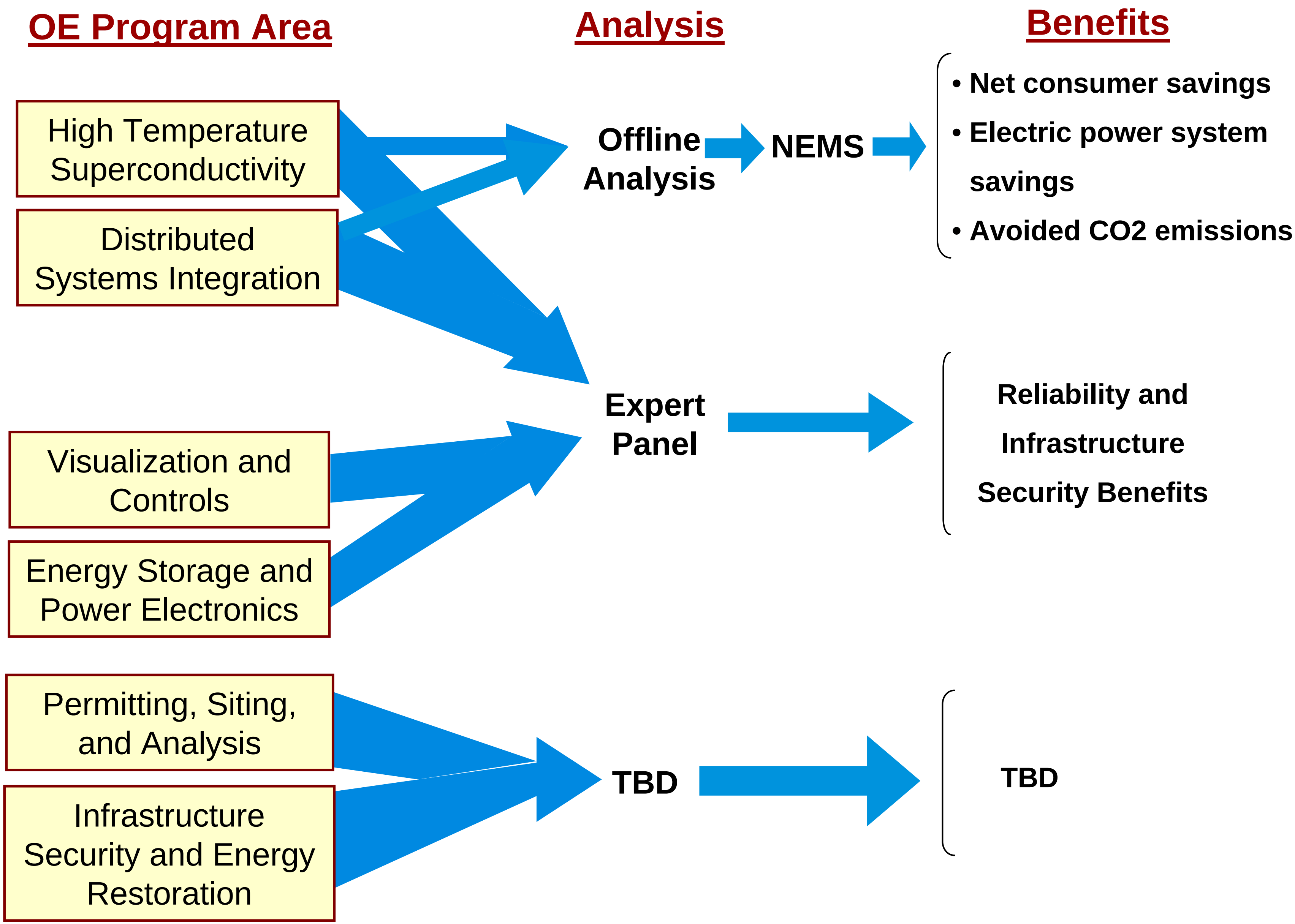
OE Program Outcomes

- Current Situation
  - Systems to supply electricity are designed and built to deliver peak electricity demand
  - Investment in transmission and distribution systems have not kept pace with demand
- Program Outcomes
  - Reduced congestion
  - Peak load reduction
  - Enhanced asset utilization
  - Enhanced system resiliency (mitigating impacts caused by accident, natural disasters, & power outages)

Issues in Measuring OE Benefits

- OE outcomes address costs associated with system reliability
  - Outages, power quality events, and congestion
- NEMS and other large-scale, integrated market models are not appropriate for estimating reliability benefits
  - Market equilibrium models: supply meets demand
  - Lacking geographical and physical detail: cannot consider congestion
  - Temporally aggregated: no consideration of short-term spikes or outages
  - Do not consider the possibility of catastrophic disruptions from terrorist attacks, cyber attacks, or major natural disasters

GPRA 08 Benefits Estimation Framework



High Temperature Superconductivity

HTS Technologies:

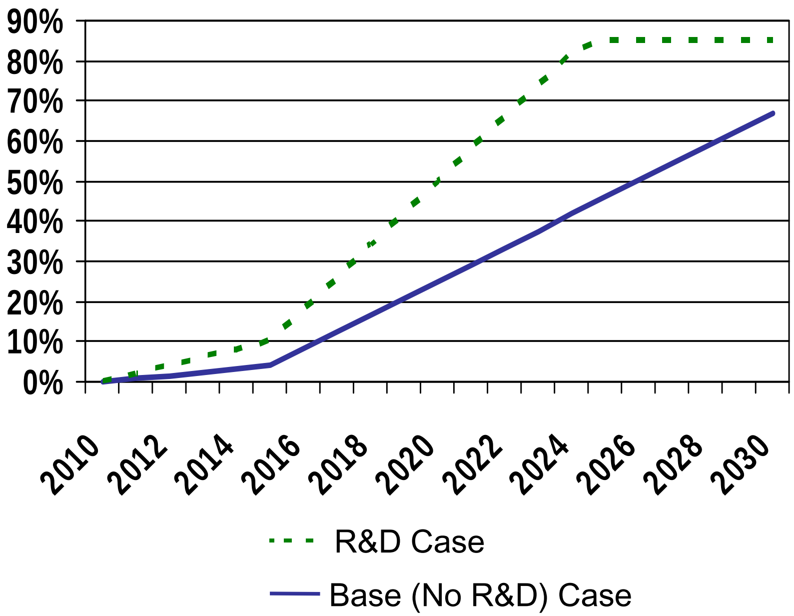
- Large Motors (<1000hp)
- Transformers
- Generators
- Underground Cables

Assumptions for Each Technology (Technology experts provided inputs for the following assumptions):

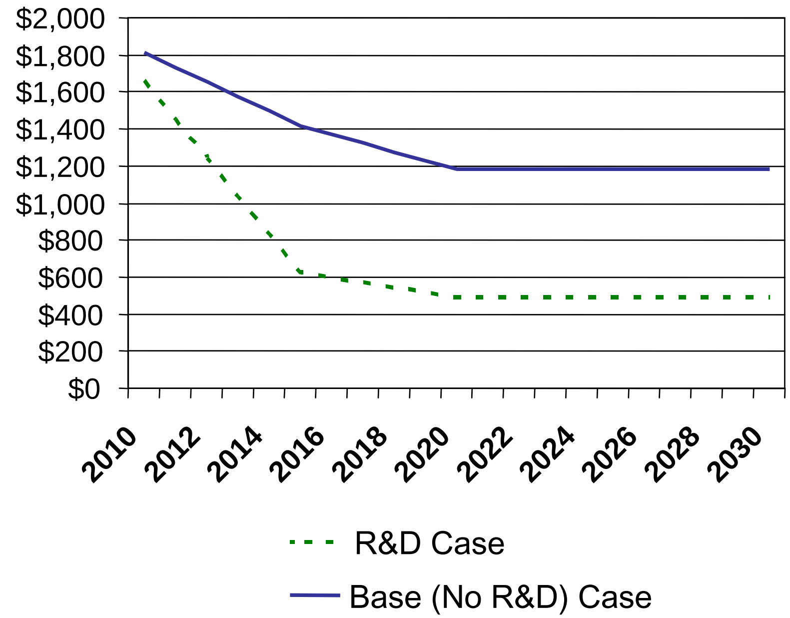
- Maximum Market – new + replacements
- Market Penetration Rate – S-Shape curve inputs
- Efficiency Differential – energy efficiency of HTS versus conventional technology
- Cost Differential – cost of HTS versus conventional technology

Example: HTS Cable Assumptions

HTS Cable Market Penetration (%)



HTS Cable Cost ($1000/mile)

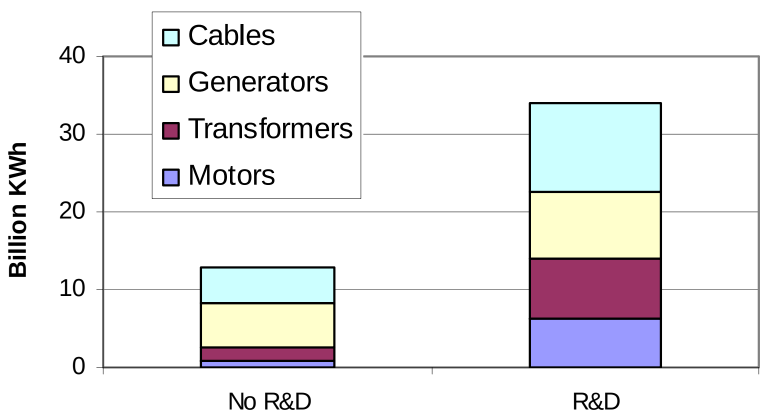


- Similar assumptions were derived for HTS motors, transformers and generators
- The AEO 2006 does not explicitly represent HTS technologies

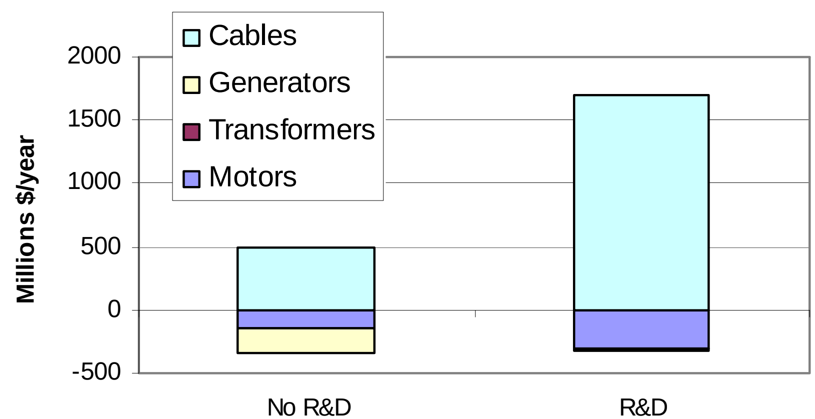
HTS Expected Savings

HTS program assumptions were translated into expected electricity and equipment cost savings, using AEO 2006 projections for electricity sales and capacity additions.

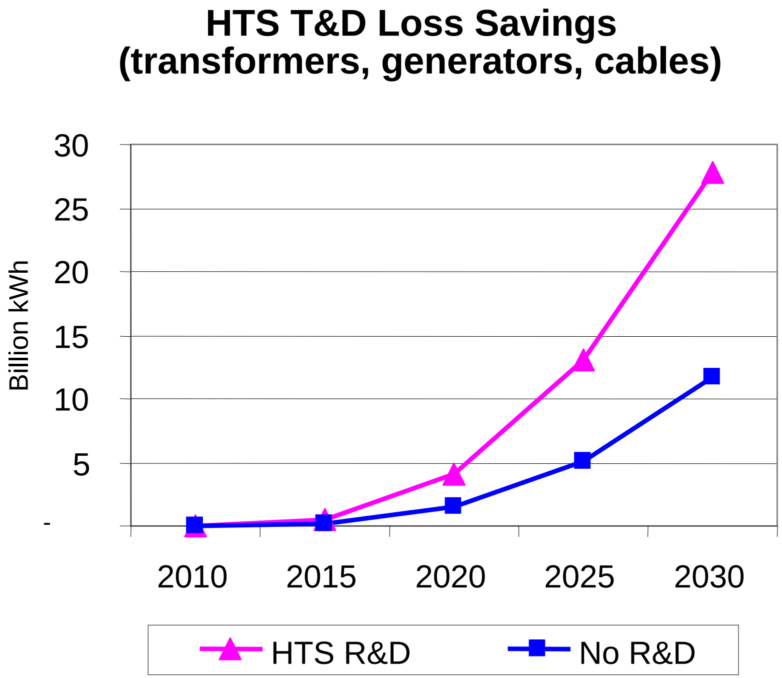
HTS Expected Electricity Savings in 2030

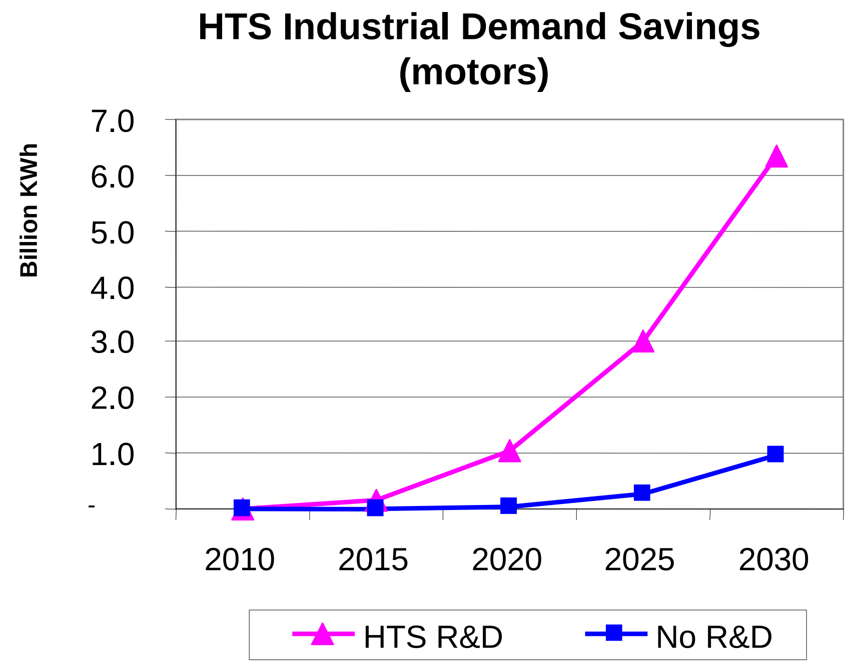


HTS Expected Equipment Cost Savings in 2030



HTS Program Energy Savings



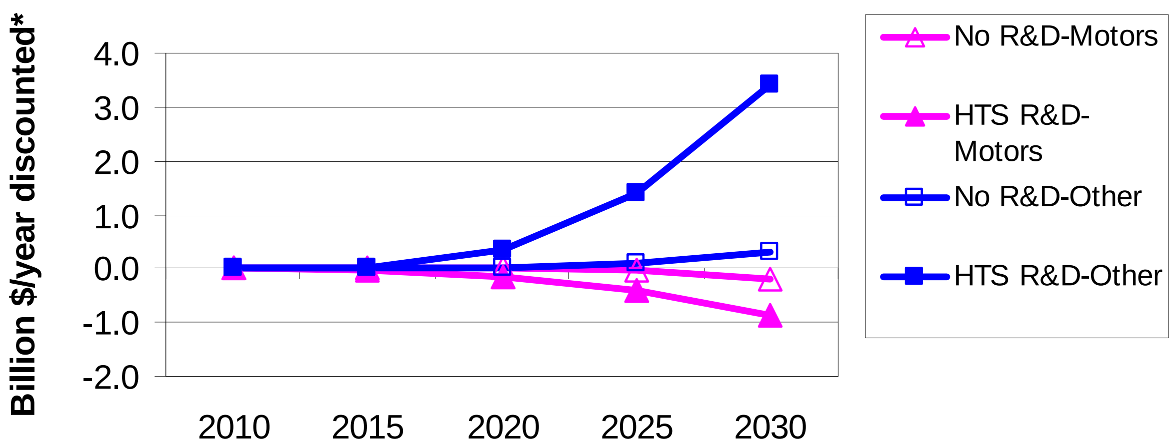


- Expected electricity savings from HTS transformers, generators and cables were represented in NEMS as T&D losses
- HTS savings from motors were represented as industrial demand savings (0.6% by 2030 in R&D case)

HTS Equipment Costs

- HTS expected equipment cost savings were amortized over the lifetime of the equipment, assuming a 3% discount rate, 15-year life for motors, and 30-year life for transformers, generators and cables.
- Amortized HTS equipment cost savings from transformers, generators and cables were subtracted from electricity system costs ($3.4 billion by 2030 in R&D case), and savings from motors were subtracted from consumer expenditures (an increase of $0.9 billion by 2030 in R&D case).

HTS Equipment Costs Relative to Conventional-Amortized* Savings



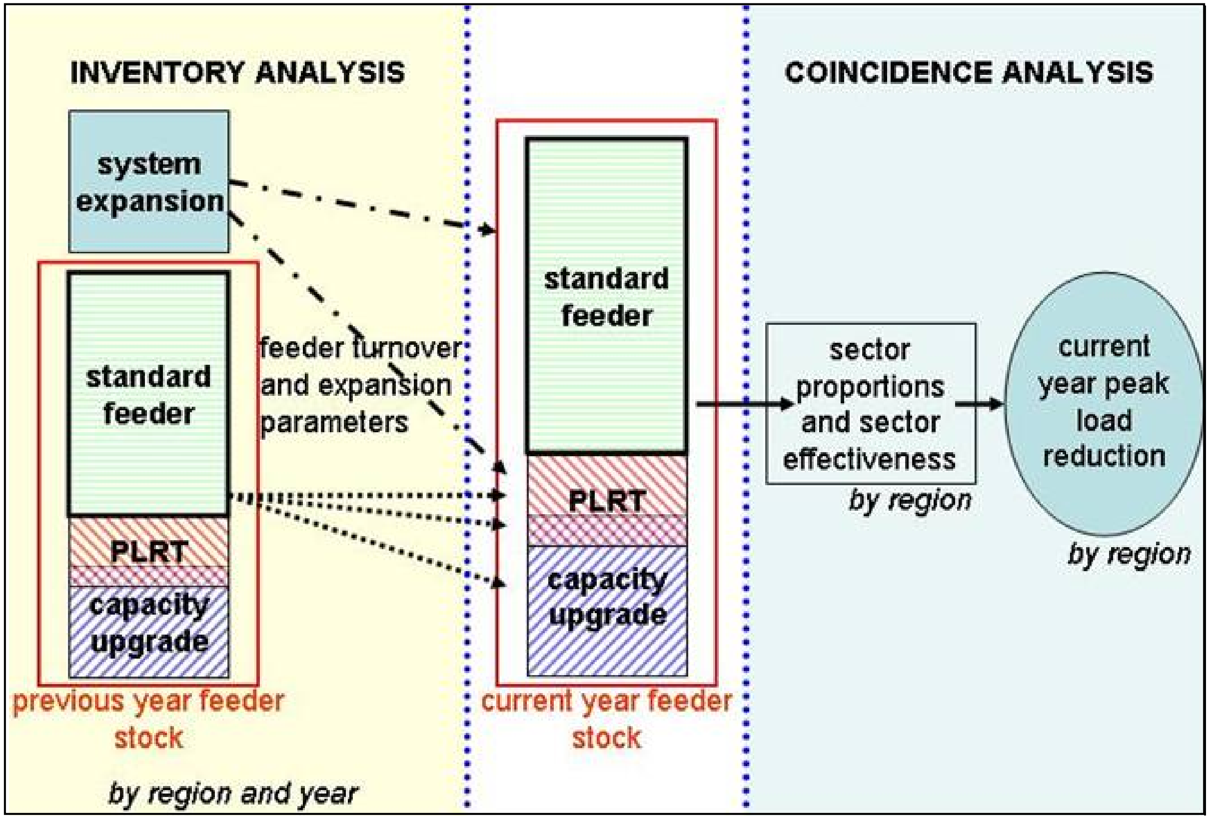
**Assumes 3 percent real discount rate. Accumulation begins in the year 2008.*

Distributed Systems Integration

- The DSI goal is “demonstrating the economic viability of a 20 percent shift in peak demand at congested electricity distribution feeders by 2015.”
- Represented in NEMS as a load-shifting technology similar to a storage technology that competes for market share in the Electricity Market Module (EMM), with technology characteristics such as capital cost, O&M costs, etc.
- Technology is economically dispatched like a storage technology by “discharging” energy during peak periods and “recharging” during off-peak periods.
- Because the DSI goal is technology neutral and because NEMS does not represent distribution feeders, an off-line analysis was conducted to derive projected market shares.

PLRT Market Penetration Model

- The Peak Load Reduction Technology (PLRT) Market Penetration Model was used to determine the projected market penetration and resulting average load shift from the DSI load shifting technology.
- The model is divided into two parts, an inventory analysis and a coincidence analysis, which are performed separately for each of the 13 NEMS EMM regions.



National Average Peak Demand Shift

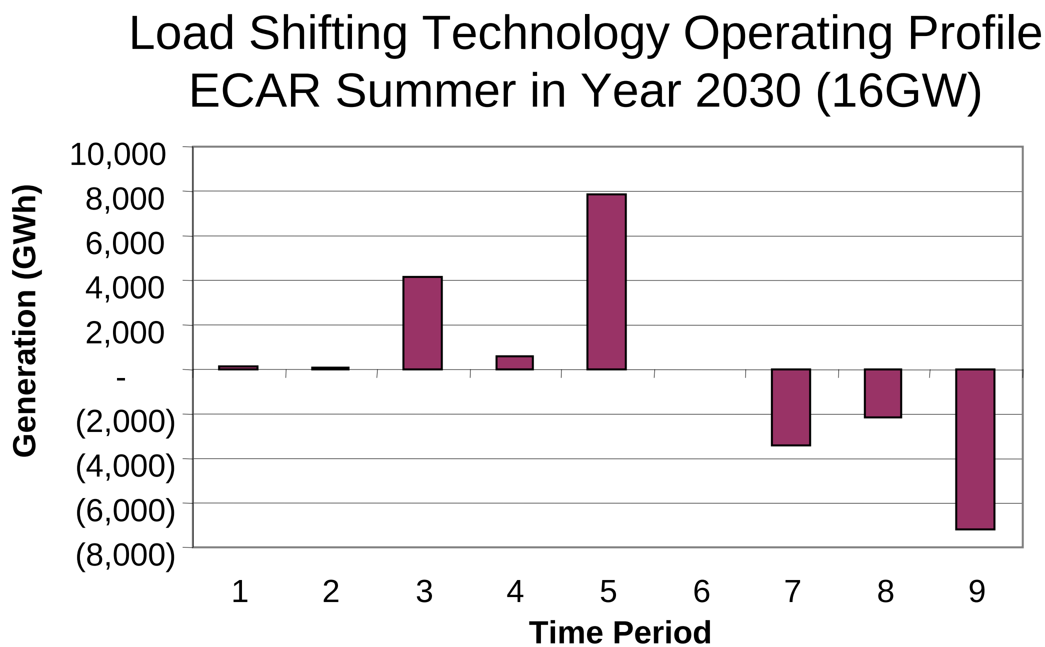
National Average Target Load Shift Projection for GPRA-NEMS FY08 Load Shifting Technology

DSI Program Case	**2017**	**2020**	**2025**	**2030**
Market Adoption (% of market)	0.0%	3.2%	17.1%	39.3%
Average Peak Load Shift (% of peak)*	0.0%	0.6%	3.4%	7.9%

*Average peak load shift is calculated as market adoption multiplied by 20% load shift per unit purchased.

- The off-line analysis calculated a projected market adoption rate adjusted for coincident peak. The national average peak load shift was calculated by multiplying the DSI goal of 20 percent load shift per unit and the PLRT projected market adoption. For the No R&D case, market share was assumed to be zero.
- Capital cost assumptions for the NEMS load-shifting technology were adjusted in order to meet the national projected market penetration, which allows the model to react if market conditions vary.

DSI Technology's Load Shifting Capability–Example



- NEMS dispatches the DSI load shifting technology economically across 9 seasonal time periods, ordered from peak (period 1) to off-peak. The number of hours in each time period varies significantly, ranging from 10 hours in period 1 to 600 hours in period 5.
- Positive generation represents the discharge of the technology (or peak shifting) during peak load hours (periods 1-5), and negative values represents the corresponding recharging during off-peak hours (periods 7-9).

Load Shifting Impacts

- The impacts associated with shifting load from peak to off-peak, include:
  - A 9% reduction in oil/gas usage associated with peak load generation from combustion turbines, resulting in reduced peak electricity prices seen by consumers.
  - A reduced demand for peak generation, resulting in a diminished need to construct new peaking electric capacity and lower system costs.
  - A reduction in natural gas process due to reduced demand for peak generation, resulting in savings to consumers.
  - Increased utilization of base load generation using coal primarily, resulting in negligible impact in reducing carbon emissions.
- These impacts are reflected in the ESE benefits of consumer savings and lower electric power system costs.

Summary of Economic and Energy Efficiency Benefits of OE's Programs

	OE BAU Portfolio Case				
	2010	2015	2020	2025	2030
ENVIRONMENTAL BENEFITS					
Avoided Carbon Emissions, Annual (MMTCE)	0	-5	-1	-4	-6
Avoided Carbon Emissions, Cumulative (MMTCE)*	0	-7	-22	-43	-66
ECONOMIC BENEFITS					
Consumer Savings, Annual (bil 2004$)	0	0	1	3	10
Consumer Savings, NPV (bil 2004$)*	0	-1	0	11	23
Electric Power Industry Savings, Annual (bil 2004$)	0	0	0	2	6
Electric Power Industry Savings, NPV (bil 2004$)*	0	1	1	5	16

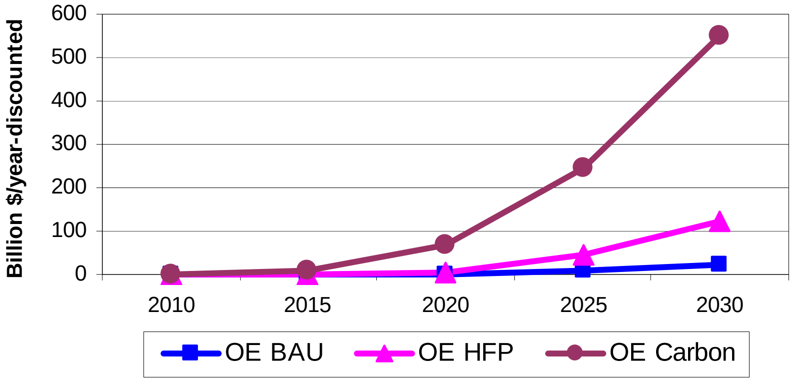
**Assumes 3 percent real discount rate. Accumulation begins in the year 2008.*

- Results show that OE programs create cumulative discounted net consumer savings of $23 billion and electricity system savings of $16 billion by year 2030.
- Carbon emissions increase due to DSI load shifting from peaking (oil/gas) generation to baseload (mostly coal) generation that is more carbon-intensive.

Alternative Scenarios

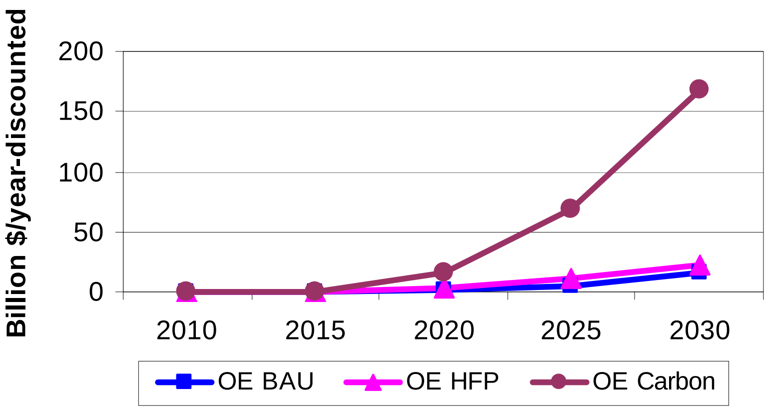
- OE programs were evaluated under two alternative scenarios: High Fuel Prices (HFP) and a Carbon Constraint Scenario as defined by the ESE Offices. OE program assumptions were not changed from the BAU scenario.
- OE programs lowered electricity and natural gas prices, resulting in higher NPV consumer expenditure savings and electric system savings relative to the BAU R&D case.

Net Consumer Expenditures
Cumulative* Savings from No R&D Case



Assumes 3 percent real discount rate. Accumulation begins in the year 2008.

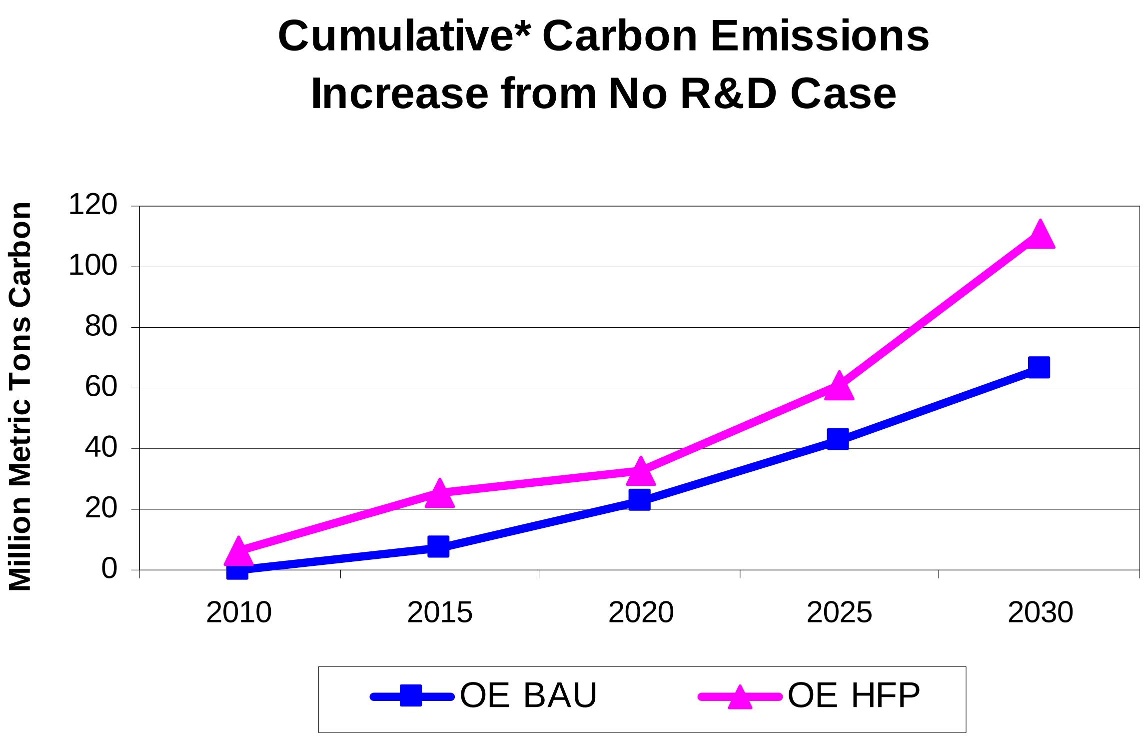
Electricity System Costs
Cumulative* Savings from No R&D Case



Assumes 3 percent real discount rate. Accumulation begins in the year 2008.

Alternative Scenario cont'd

- Lower electricity prices resulting from OE programs increased electricity demand and carbon emissions in HFP R&D case relative to the BAU case. In a carbon constraint scenario, there are no carbon savings to measure.

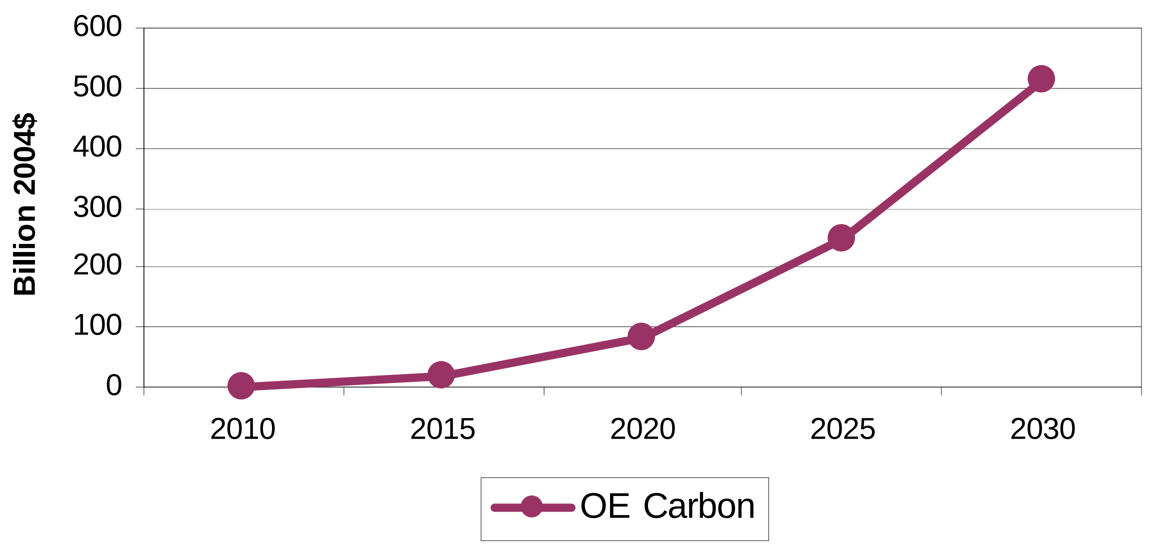


**Accumulation begins in the year 2008.*

Cost of Carbon Allowances

- The Cost of Carbon Allowances is measured as the model's allowance price ($ per ton carbon) in each year multiplied by the emissions cap. OE programs reduced the allowance price by allowing non-carbon nuclear and renewable technologies to be used to meet peak load.

Cost of Carbon Allowances, NPV*
Savings from Carbon No R&D



**Assumes 3 percent real discount rate. Accumulation begins in the year 2008.*

Reliability and Infrastructure Security Definitions

- **Reliability**

  The "reliability" of an electric power system is the degree to which it delivers power to consumers in the amount desired and within acceptable standards. The reliability of a system may be assessed with respect to its:

  – Adequacy – The ability of the electric system to supply the aggregate electrical demand and energy requirements of consumers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements; and

  – Operational Reliability – The ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements.

- **Infrastructure Security**

  The (in)security of energy system infrastructure refers to its vulnerability to highly disruptive catastrophic events, and to the system's ability to respond and recover in such an event. Infrastructure includes both physical and cyber systems.

Reliability and Security Benefits

- **Reliability**

  Technologies and designs that lead to reductions in the costs of:

  – Outages – frequency, duration, number affected, sectors affected

  – Power quality events – deviations from sine wave defined by standards

  – Transmission congestion – difference between delivered cost with constraint vs, unconstrained transmission

- **Infrastructure Security**

  Technologies and designs that lead to:

  – Reduced likelihood of a major attack or other catastrophic event

  – Mitigated damage to the nation, if such an event occurs, using technologies or systems that provide a supply response (stored energy, micro-grid islands, optimal switching, …)

  – Reduced damage to the nation, if such an event occurs, due to technologies or systems that induced a demand response (e.g., prior load shifts)

2002 Current Estimates of Total Annual Costs in Each of the Three Reliability Categories (from the literature) [$ billions per year]

	Low	Mid	High
Outages	22	79	135
Power Quality Events	6	24	34
Transmission Congestion	0.15	1	2.6

Motivation for Alternative Analysis Approach

- National Energy Modeling System (NEMS) and other large-scale integrated energy market models not appropriate for estimating reliability or infrastructure security benefits
- Aggregate and lacking in geographic detail
- Calculate market equilibrium in deterministic way
- Whereas, reliability and security concerns arise because of variability in supply and demand
- Do not consider possibility of catastrophic disruptions from terrorist attacks, cyber attacks, or major natural disasters
- Approach needed that complements NEMS, using key NEMS inputs and outputs, to be consistent with ESE-wide analyses
- In transitioning to development of such a model to estimate reliability and security benefits, we used expert panels as an interim approach for the FY08 budget request

Expert Panels Assessment

- Expert panels for each of the 4 OE programs
- Questions, estimates, and commentary about impact of OE programs (i.e., with and without) on market penetration of technologies, and impact on reliability and infrastructure security
  - Outage costs; and allocation to frequency, duration, and extent
  - Cost of power quality events
  - Transmission congestion cost
  - Likelihood of attack or other catastrophic disaster
  - Mitigation of damages from supply responses
  - Mitigation of damages from demand responses
- Program summaries and key NEMS inputs or outputs provided to panel → consistent and common set of background information
- Panel provided 3 rounds of estimates to same questions about impacts of R&D, with and without OE

Three Rounds of Panel Reviews to Revise and Refine Estimates and Supporting Reasons

- 1st round: independent estimates and reasoning by each panelist provide a preliminary Program Case
- 2nd round: revised Program Case estimates based on panelists’ review of other panelists’ estimates and reasoning, and on clarifications of program goals and questions
- 3rd round: Portfolio Case estimates based on sharing 1st and 2nd round information among all panelists and among all four panels, revised NEMS runs, and other information

Summary of Reliability and Infrastructure Security Benefits

Program or Portfolio	Outages ($ billions)		Power Quality Events ($billions)		Trans-mission Congestion ($ billions)		Total Reliability ($ billions)		Risk of Attack or Destruction (%)		Mitigating Damage with Supply (%)		Mitigating Damage with Demand Response (%)		Total Infra-structure Security Improve-ment	
	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
DSI	1.9	5.3	0.51	1.6	0.03	0.09	2.4	7.0	2.0	5.0	2.0	3.0	1.0	2.0	5%	10%
HTS	1.9	5.3	0.29	1.3	0.01	0.07	2.2	6.7	2.0	3.0	2.0	4.0	2.0	5.0	6%	12%
ES&PE	2.8	4.3	1.0	1.7	0.05	0.09	3.9	6.1	4.5	4.0	5.0	8.5	2.0	4.0	11%	16%
V&C	9.5	11	1.1	1.6	0.07	0.07	11	12	10	10	10	7.5	10	7.5	28%	24%
PORT-FOLIO	4.7	11	1.2	1.7	0.07	0.13	6	13	5	4	4	13	7	9	13%	19%

Reliability benefits are expressed as annual reduction in system costs; security benefits are expressed as percentage reduction in risk of power disruptions associated with a catastrophic attack or natural disaster.

Future Steps

- Define reliability and security metric for OE
- Develop and apply a methodology to measure the benefit derived from achieving the metric
- Develop methodologies for measuring economic benefits of various OE programs, e.g.,
  - Examining impact of OE policies on enhancing the utilization of wind and other renewable technologies
  - Determining transmission cost reductions due to advancements in high-voltage power electronics and control technologies.